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Topography and the structure of the surface of polyamide - glass composites after the ageing process

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Properties

ABSTRACT

Purpose: Polymers have found applications in such diverse biomedical fields as tissue engineering, implantation of medical devices and artificial organs, prostheses, ophthalmology, dentistry, bone repair and many other medical fields. The requirements for materials used in the construction of removable dentures are becoming more and more demanding. The introduction of improved flexible materials has been a considerable advance. The aim of this work was to determine how the structure of thermoplastic materials changes over time in terms of weight changes and artificial saliva sorption. Purpose of this paper was to evaluate the influence of the ageing process on structure of polyamide - glass composites applied in dentistry.

Design/methodology/approach: Polyamide samples about the diversified content of the glass fibre were produced with method of the injection moulding. Denotation the absorbency of artificial saliva was performed on standardized samples according to the norm. Samples were dried off to fixed mass, and then they were soaked in artificial saliva. Three temperatures of examination were applied 20ºC, 35ºC and 50ºC.

Findings: Examinations allowed to show that the absorbency of artificial saliva through composite is dependent on the temperature.

Research limitations/implications: To fully evaluate the influence of the ageing process on mechanical properties of polyamide - glass composites applied in human body environment it is planned to continue described research. Simultaneous influence of the ageing process on mechanical properties of polyamide - glass composites will be tested.

Originality/value: Applying strengthened thermoplastics with glass fibre on dentures is a new look at materials applied in dentistry.

Keywords: Biomaterials; Biocomposites; Structure; Dental Prosthesis

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1. Introduction

Biomaterials are materials of natural or man-made origin that are used to direct, supplement, or replace the functions of living tissues of the human body. Over the centuries, advancements in synthetic materials, surgical techniques, and sterilization methods have permitted the use of biomaterials in many ways. Biomaterials in the form of implants (vascular grafts, sutures, bone plates, heart valves, intraocular lenses, ligaments, dental implants, etc.) and medical devices (pacemakers, biosensor, artificial hearts, blood tubes, etc.) are widely used to replace or restore the function of traumatized or degenerated tissues or organs, to assist in healing, to improve function, to correct abnormalities, and thus improve the quality of life or the patients. Biomaterials are expected to perform in our body`s internal environment, which is very aggressive. For example the pH of body fluids in various tissues varies in the range from 1to 9 [1-9].

In determining the effect of the body on the implant, the material must be examined for changes such as: degradation or other changes in molecular structure (i.e. crosslinking or phases); changes in mechanical properties; wear particles; state of hydration; elution of low molecular weight species; protein saturation or oxidation of the surfaces; cellular ingrowth calcification [1-4].

Polymers remain the most universal class of biomaterials, being extensively applied in medicine and biotechnology, as well as in the food and cosmetic industries. The application of polymeric materials for medical purposes is growing very fast. Polymers have found applications in such diverse biomedical fields as tissue engineering, implantation of medical devices and artificial organs, prostheses, ophthalmology, dentistry, bone re-vectors and many other medical fields.

Correct understanding of physical, electrical and mechanical properties of polymers has high influence on their use in dentistry. It is essential mainly because materials used in that trade are exposed to the influence of the oral cavity environment and occlusion bite forces. Moreover, dentures undergo periodic cleaning and polishing procedures during various prophylactic activities. In order to successfully apply a polymer material in dentistry, it is essential to optimally choose its properties. Polymers used in dentistry have to meet specific biologic, strength and technological standards.

Most importantly, they [2-3]:

- should be non-toxic,
- should not cause oral cavity and other tissue irritation,
- should not cause allergic reactions,
- should be resistant to various physical and chemical factors that occur in the oral cavity environment,
- should have adequate strength, hardness, rigidity and abrasion resistance.

Dental prostheses are prosthetic restorations commonly used in implant dentistry. One of the most familiar types of prosthesis is dentures. Different dental prosthesis options fall into two general groups: removable and non-removable. Removable prostheses are generally easy to clean and maintain. Although they are typically less expensive than non-removable restorations, they are not as stable and require a longer adjustment time than complete non-removable prostheses. Non-removable prostheses offer patients a sense of having a permanent tooth replacement. However, they are also difficult to clean and are more prone to recurrent dental disease. Therefore, patients with non-removable prostheses must maintain a high level of hygienic vigilance when caring for their restorations [8-11].

Flexible dentures, the latest prosthodontic solutions also known as nylon dentures, are perfect alternatives to conventional and partial acrylic dentures. Made of a special thermoplastic material, flexible dentures are highly comfortable as well as resistant to breaking (Fig. 1) [12].

In comparison to conventional acrylic dentures, they have numerous advantages that make denture wearing incredibly easy and pleasant for patients:

- they are much thinner than conventional dentures,
- they stay firmly in place (have better stability and retention) and do not slip or fall off,
- they do not produce allergic reactions,
- they have no metal clasps but aesthetic gum tissue-colour clasps made of thermoplastic nylon,
- they are lightweight and flexible; they do not break and crack
- they take up less space in oral cavity.

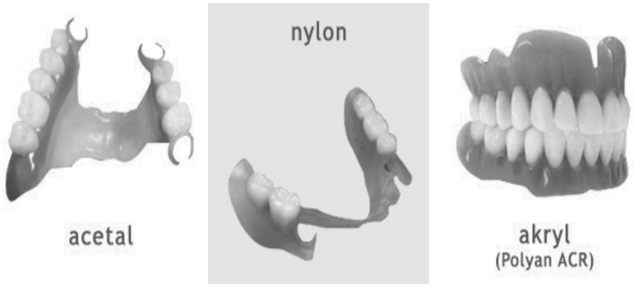


Fig. 1. Examples of partial prostheses [12]

The application of nylon-like materials to the fabrication of dental appliances has been seen as an advance in dental materials. This material generally replaces the metal, and the pink acrylic denture material used to build the framework for standard removable partial dentures.

Thermoplastic resins and co-polymers have many advantages over conventional powder or liquid resin systems. Thermoplastic resins tend to have predictable long-term performance. They are stable and resist thermal polymer unzipping. They also exhibit high creep resistance and high fatigue endurance as well as excellent wear characteristics and solvent resistance. Thermoplastic resins typically have very little or almost no free monomer in the material. A significant percentage of the population is allergic to free monomer and these materials offer a new safe treatment alternative for these individuals. In addition, thermoplastic materials have almost no porosity, which reduces biologic material build up, odors, and stains and exhibit higher dimension and color stability. All of these factors become important when producing long-term provisional prostheses during implant or complex restorative cases, or when used for permanent removable appliances. Typically, the thermoplastic resins are more flexible and stronger than their traditional counterparts are. Elastomeric resins can be added to the resin polymer formulas to create greater flexibility, which reduces fracturing. Thermoplastic resins can also be reinforced with glass filler or fibers to further enhance their physical properties. At the same time, these restorations can be relined and repaired, by repressing the restoration. The thermoplastic resins can produce single cast or pressed restorations that are strong, lightweight, flexible appliances in tissue or tooth color matched materials that never need adjusting. These restorations display excellent esthetics and provide long-term comfortable use for the patient. This provides excellent alternative cosmetic restorations for esthetic-conscious patients [16].

Thermoplastic resins are used for a broad variety of applications from removable flexible partial dentures, preformed partial denture clasps, fiber reinforced fixed partial dentures temporary crowns and bridges, provisional crowns and bridges, obturators and speech therapy appliances, orthodontic retainers and brackets, impression tray and border molding materials, occlusal splints, sleep apnea appliances, and implant abutments [16].

Composites are becoming more commonly used in dental and medical applications to replace metal and polymer materials. Composites are materials that consist of two or more types of different components (e.g. metal, ceramic or polymer) and they offer a variety of advantages compared to one-component materials [20]. For example, in dental applications, composites are better esthetically (based on color) than metals and they possess the good component qualities of the composite, such as the high strength of fibers in fiber-reinforced composites, which have been successfully used for example in fixed partial dentures [1]. In FRC, the polymer matrix itself is not durable enough for load-bearing applications but, with the aid of reinforcing fibers, the strength of the composite increases [17-19, 21-22].

2. Experimental setup

Determining the influence of the absorbency of polyamide glass composites on topography and the structure of the surface was a purpose of research.

For the research on the absorbency 45 standardized samples of the polyamide with the addition 2%, 4%, 6% of glass fibre were used Samples before the accession to examinations were left weighed and described (Fig. 2.).

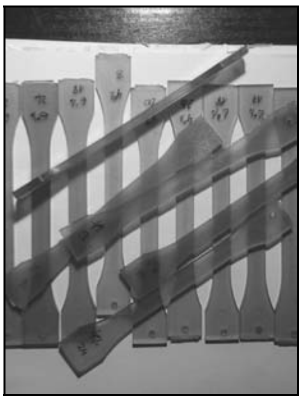


Fig. 2. Samples for examinations

With a view to conducting research preparing artificial saliva was essential. Chemical reagents for the preparation should be about the analytical cleanness and dissolved in the water about the II degree of purity according to ISO 3696 [22]. The chemical composition of artificial saliva was described in Table 1.

Table 1.
Chemical reagents to artificial saliva [24]

Artificial saliva	
Na_2HPO_4	0.260 g/l
NaCl	0.700 g/l
KSCN	0.330 g/l
KH_2PO_4	0.200 g/l
$NaHCO_3$	1.500 g/l
KCI	1.200 g/l

Samples of the polyamide with addition 2%, 4% and 6% of glass fibre were put in solution of artificial saliva (Fig. 3) in temperatures 20°C, 35°C and 50°C, were subjected to the ageing process. The absorbency was determined according to according to the model [23]:

$$c = \left(\frac{m_2 - m_1}{m_1} \right) \cdot 100 \tag{1}$$

where:

m_1- mass of the sample, in milligrams (mg),
m_2- mass of the sample, in milligrams (mg), by the draught.

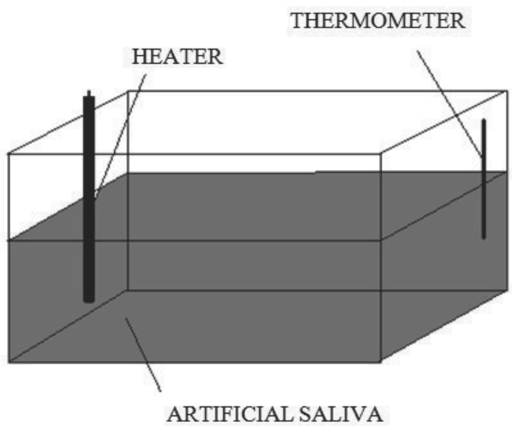


Fig. 3. Scheme of research

3. Results

Results of measurements of the absorbency were presented in Figures 4, 5, 6. Examinations allowed to show that the absorbency of artificial saliva through composite is dependent on the temperature. The high temperature of artificial saliva caused faster absorbing by composite.

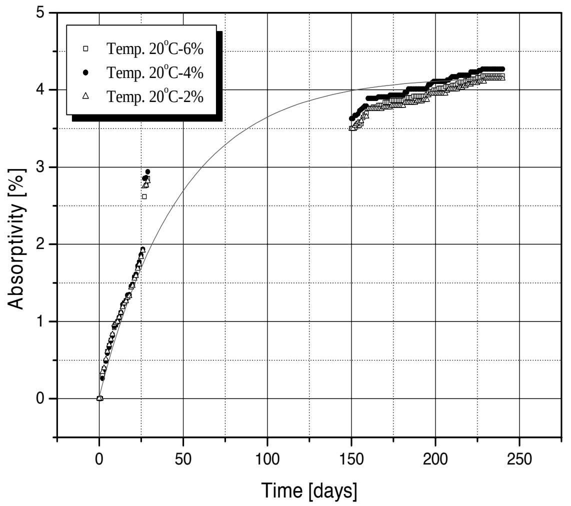


Fig. 4. Graph of the dependence of the absorbency on the time in temperature 20°C

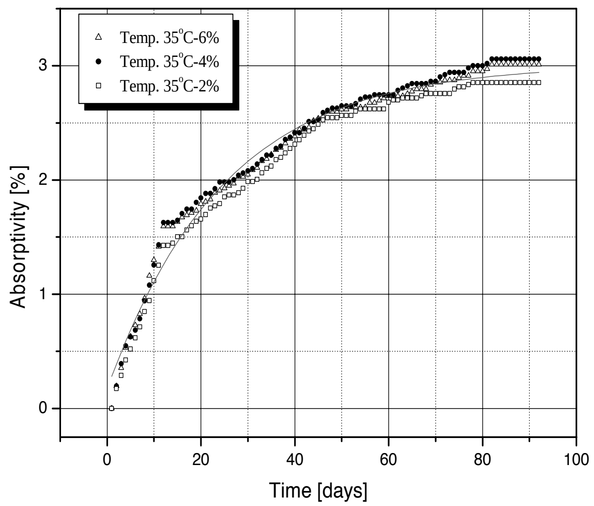


Fig. 5. Graph of the dependence of the absorbency on the time in temperature 35°C

On graphs showing the absorbency of composite (Figures 4, 5, 6) most quickly samples stabilized in temperature 50°C, it came after 67 days. However in temperature 20°C, the stabilization of samples lasted the over half year. In temperature 35°C the stabilization came after 83 days.

From graphs of the absorbency, it results that the minimum value of the absorbency was made a note for samples in temperature 35°C.

Results of measurements were approximating with the following function:

$$y = A1*\exp(-x/t1) + A2*\exp(-x/t2) + y0 \quad (2)$$

where: y - absorptivity, %.

Values of coefficients of approximating functions for adequate temperatures were described in Table 2

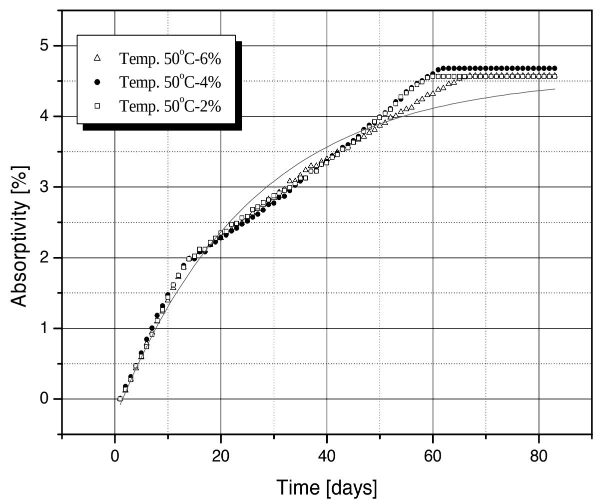


Fig. 6. Graph of the dependence of the absorbency on the time in temperature 50°C

Table 2.
Coefficients of the approximating function results of measurements of the absorptivity

Coefficients of the function	Temperature, °C		
	20	35	50
R^2	0.99757	0.98716	0.99508
y0	4.81963	3.31149	19.76543
A1	-2.98475	-1.09894	-17.95156
t1	52.80625	5.30479	462.3132
A2	-1.58634	-2.34305	-2.04197
t2	195.41739	44.03283	8.58655

Table 3 is showing photographs, structure and topography of the surface of composite with content 2% of glass fibre. However Table 4 is showing photographs, structure and topography of the surface of composite with content 4% of glass fibre. Table 5 is showing photographs, structure and topography of the surface of composite with content 6% of glass fibre.

In photographs of samples changes are visible on the surface of composites ageing in temperature 50°C. These changes are appearing in the form of the white coating on edges of samples. This coating is appearing on every of samples irrespective of the content of the glass fibre.

There are visible corrosion pits and losses on the surface of material. However on samples ageing in temperature 20°C isn't appearing coating. It is possible also to observe that the structure is much smoother than in case of composites ageing in temperatures 50°C and 35°C.

4. Conclusions

Examinations allowed to show that the absorbency of artificial saliva through composite is dependent on the temperature. The high temperature of artificial saliva caused faster absorbing by composite.

On the basis of achieved results it is possible to make the following conclusions:

- the absorbency of the polyamide is independent of the percentage content of the glass fibre,
- the change of dimensions is comparable for all samples,
- the temperature was precipitating the process of saturating composite.

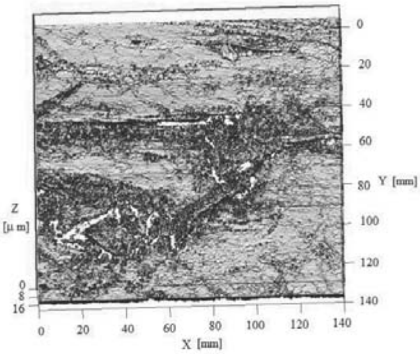
Table 3.
Photographs, structure and topography of the surface of composite with content 2% of glass fibre

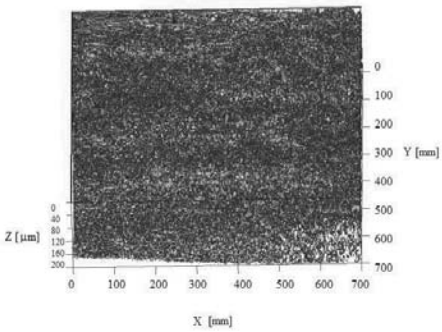
Content of fibre		
2%		
Temperature, °C		
20°C	35°C	50°C

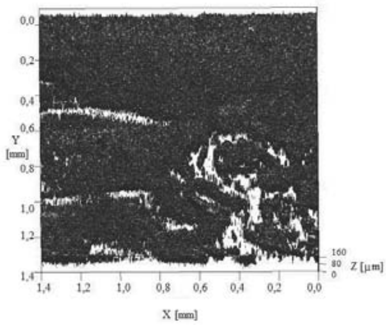
Picture of samples



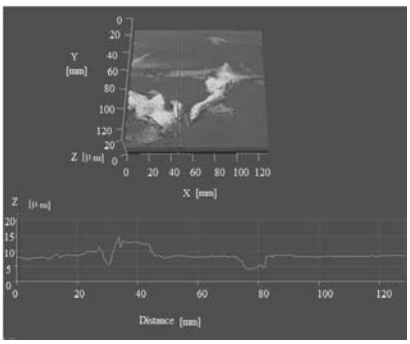
Structure of samples

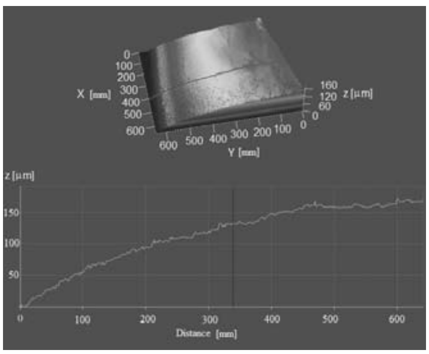






Topography of the surface of the samples





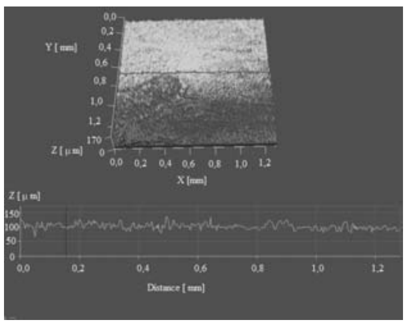
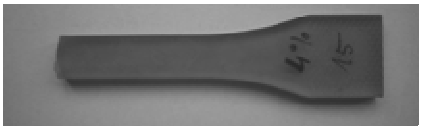
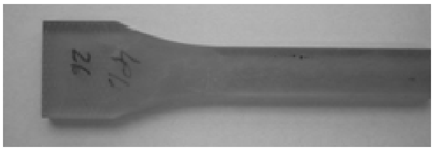
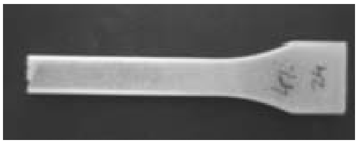
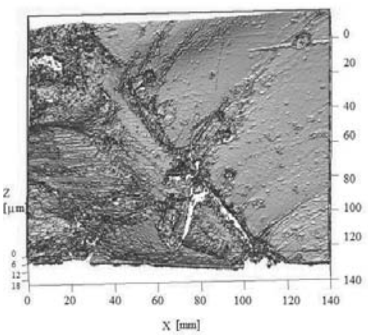
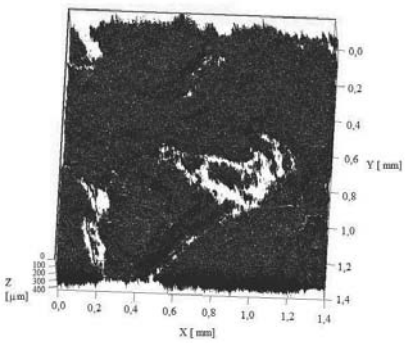
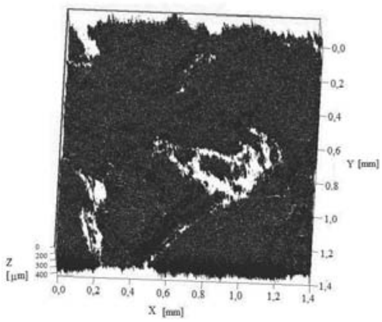


Table 4.
Photographs, structure and topography of the surface of composite with content 4% of glass fibre

<table>
<tr><td colspan="3">Content of fibre</td></tr>
<tr><td colspan="3">4%</td></tr>
<tr><td colspan="3">Temperature, °C</td></tr>
<tr><td>20°C</td><td>35°C</td><td>50°C</td></tr>
<tr><td colspan="3">Picture of samples</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">Structure of samples</td></tr>
<tr><td>
</td><td>
</td><td>
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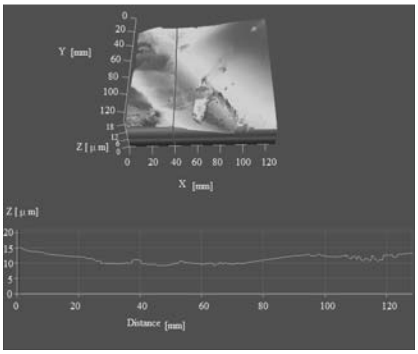
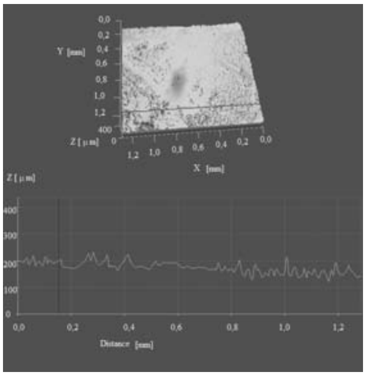
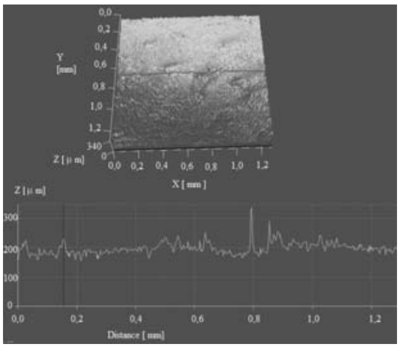
<tr><td colspan="3">Topography of the surface of the samples</td></tr>
<tr><td>
</td><td>
</td><td>
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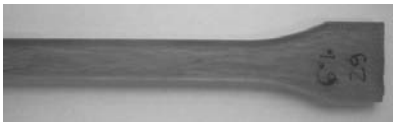
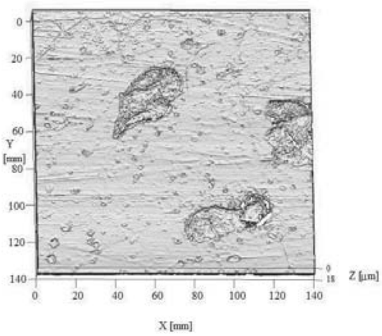
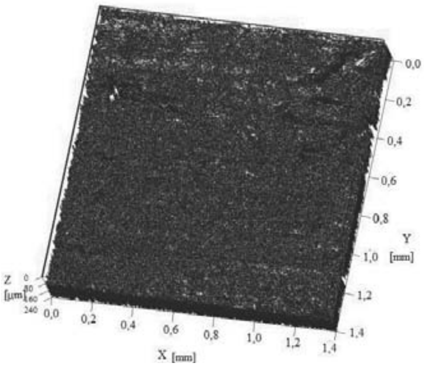
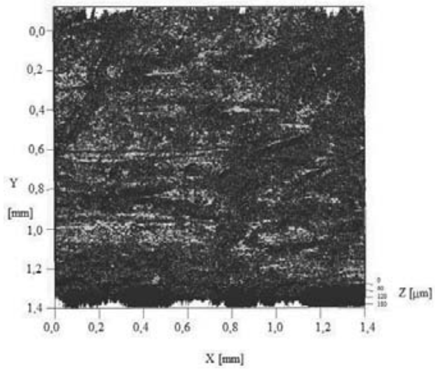
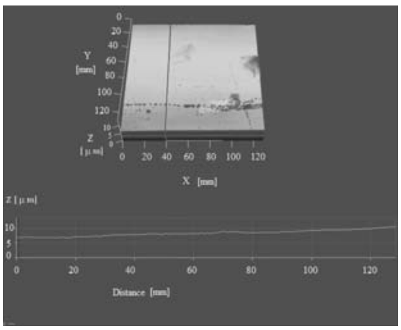
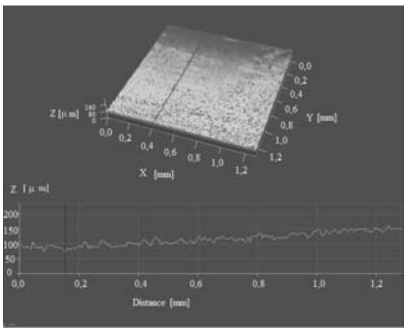
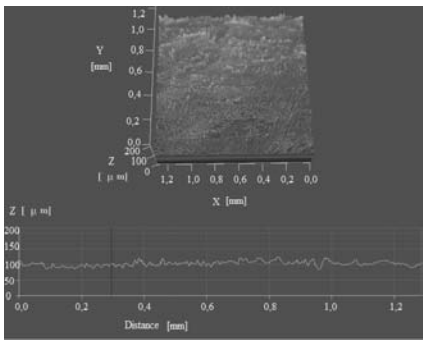
Table 5.
Photographs, structure and topography of the surface of composite with content 6% of glass fibre

Content of fibre		
6%		
Temperature, °C		
20°C	35°C	50°C
Picture of samples		
		
Structure of samples		
		
Topography of the surface of the samples		
		

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